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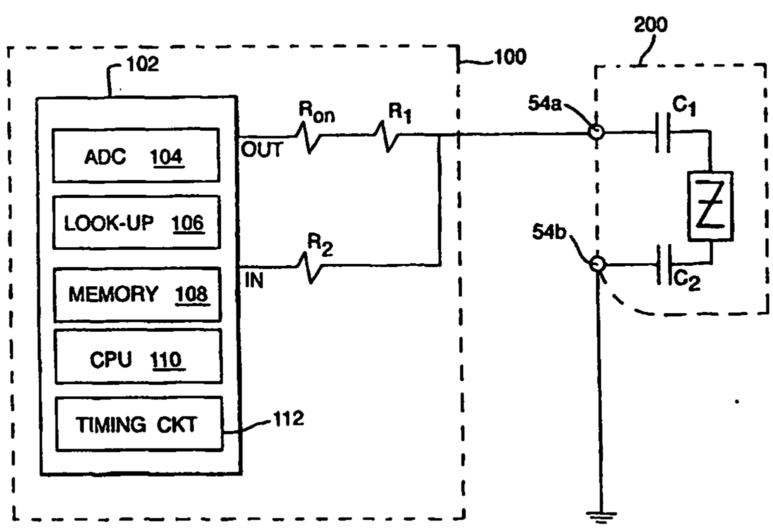

(57) Abstract

A conductivity measurement system provides one or more DC pulses to first and second electrodes submerged in an aqueous solution such as, for instance, the wash water of an industrial dishwasher. The voltage at the first electrode is measured at first and second predetermined times after initiation of DC pulse(s). Linear regression of the first and second measured voltages is used to calculate the voltage at the first electrode at the beginning of the DC pulse(s), i.e., at time t=0. The resulting voltage at time t=0 is then used to calculate the conductivity of the solution, thereby compensating for the effects of polarization. Further, the difference between the respective first and second measured voltages is compared to a predetermined threshold value to determine whether the electrodes are so contaminated that polarization compensation is no longer feasible, thereby signaling that the electrodes should be cleaned or replaced.

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APPARATUS AND METHOD FOR CONDUCTIVITY MEASUREMENT INCLUDING PROBE CONTAMINATION COMPENSATION

Field of Invention

The present invention relates generally to conductivity measurement systems and the low-cost probes thereof, such as used in commercial dishwashers, and particularly to conductivity measurement systems, which compensate for probe contamination.

Description of Related Art

Industrial dishwashers use conductivity measurement systems to maintain proper detergent concentrations in the dishwashers' wash water. Conductivity measurement systems are well known and typically include a probe that has first and second electrodes submerged in the wash water. A signal from a source circuit is applied to the electrodes to induce a current between the electrodes. This current, which is mirrored in the source circuit, is determined by dividing the voltage in the source circuit by the impedance of the source circuit. The conductivity of the wash water is then determined by dividing the current between the electrodes by the voltage across the electrodes.

Current flow in an aqueous solution, e.g., the wash water, is facilitated by the flow of ions between the electrodes. In an industrial dishwasher, the ions are provided by the detergent. Thus, increasing the detergent concentration results in a corresponding increase in the conductivity of the wash water. The relationship between wash water conductivity and detergent concentration for a particular detergent is typically stored in a look-up table, thereby

allowing detergent concentration to be easily derived from wash water conductivity.

As current is induced between electrodes in an aqueous solution, ions begin accumulating on one of the electrodes. The ions accumulating on the electrode surface each occupy a finite space such that after a time period t there is no more available surface area on the electrodes on which ions may accumulate. This phenomena, known in the art as polarization, reduces current flow between the electrodes and may result in erroneous conductivity measurements which, in turn, lead to erroneous detergent concentration measurements. Thus, when the electrodes become polarized, the detergent concentration of the wash water is perceived by the dishwasher to be too low, thereby leading to the addition of detergent to wash water that may, in reality, already be of a desired detergent concentration. Further, when used as described above, the electrodes undesirably accumulate non-conductive particles thereon which, in turn, reduce the effective area of the electrodes. As a result, contamination of the electrodes speeds the above-described polarization of the electrodes and, therefore, diminishes the useful life of the electrodes.

In theory, the effect of polarization upon conductivity measurements can be eliminated by calculating conductivity the instant current is induced between the electrodes, since at time t=0 ions have not yet accumulated on the electrodes. Here, the voltage between the electrodes must be measured just as the source signal that induces current in the wash water is asserted. Unfortunately, such an approach is not feasible. First, there are significant

characteristic variations between ion species during the first 1-2 microseconds of aqueous current flow. Since the ion species of the detergent is typically unknown, measurements taken within the first 1-2 microseconds are unreliable. Second, it is very difficult to fabricate a circuit which can produce a source pulse and then immediately capture an analog reading produced by the source pulse.

US-A-4,756,321 discloses an industrial dishwashing system in which a continuous AC signal is applied to first and second electrodes submerged in wash water to induce a current between the electrodes. The resulting current is measured over time, and then used to calculate the conductivity of the wash water. Conductivity is then converted into a logarithmically scaled detergent concentration. Here, the continuous current flow between the electrodes results in a continually increasing polarization of the electrodes. As a result, the electrodes must be either cleaned or replaced at regular intervals. The servicing of the electrodes is not only expensive, but also reduces operating efficiency of the dishwasher. Further, this system's inability to measure or predict electrode contamination makes it even more difficult to optimize the useful life of the electrode.

Another approach involves driving the electrodes with a pulsed DC signal as described, for instance, in US-A-4,119,909. In that system, the pulsed DC signal induces short pulses of current between the electrodes in the wash water. Use of short current pulses reduces polarization and, thus, increases the useful life of the electrodes, as compared to the averaging technique disclosed in US-A-4,756,321. However, conductivity measurements provided by

this approach are nevertheless influenced by polarization. Further, this system is unable to measure or predict electrode contamination. It is therefore difficult to accurately determine when or at what rate the measured conductivity deviates from the actual conductivity and, as a result, the accuracy with which this approach maintains the detergent concentration at a target level is compromised. It is thus also difficult to maximize the intervals at which the electrodes are cleaned or replaced and, therefore, difficult to maximize the useful life of the electrodes.

Definition of the invention

An apparatus and method for measuring conductivity of an aqueous solution are disclosed which compensate for polarization and provide warning of electrode contamination. In accordance with the present invention, one or more DC pulses are applied to first and second electrodes submerged in an aqueous solution such as, for instance, the wash water of an industrial dishwasher. The voltage at the first electrode is measured at first and second predetermined times after initiation of the one or more DC pulses. The difference between the respective first and second measured voltages is calculated and then compared to a predetermined threshold value. If the difference voltage exceeds the predetermined threshold value, thereby indicating that the electrodes are sufficiently contaminated so as to soon require cleaning or replacement, an alarm signal is asserted. In this manner, present embodiments maximize the useful life of the electrodes and, thus, minimize servicing costs.

Further, present embodiments provide conductivity measurements compensated for polarization. Linear regression of the first and second measured voltages is used to calculate the voltage at the first electrode at the beginning of the one or more DC pulses, i.e., at time t=0. The resistivity of the solution is calculated using Ohm's Law, and then converted into conductivity according to the known K factor of the solution. In some embodiments, conductivity is provided in logarithmically scaled measurement units, known in the art as Beta units. Since the conductivity of the solution is calculated according to the electrode voltage at the beginning of the DC pulse, the measured conductivity of the solution is not influenced by polarization. In this manner, present embodiments effectively compensate for polarization, and thereby produce a more accurate conductivity measurement, as compared to the prior art. As a result, present embodiments greatly reduce the likelihood of incorrect detergent concentrations resulting from erroneous conductivity measurements.

Brief description of the drawings

Fig. 1 is a block diagram of an industrial dishwasher in which a conductivity measurement system in accordance with the present invention is used;

Fig. 2 is a block diagram of a micro-controller suitable for use in the conductivity measurement system of Fig. 1, including a schematic diagram of a four-layer capacitor modeling the polarization of wash water;

Fig. 3 is a timing diagram showing various signals associated with the operation of one embodiment of the present invention; and

Fig. 4 is a flow chart illustrating operation of a conductivity measurement system in a preferred embodiment of the present invention.

Like components in the Figures are similarly labeled.

Detailed description

Principles of the present invention are described below with reference to the industrial dishwasher 20 disclosed in US-A-4,756,321, incorporated herein by reference, for simplicity only. It is to be understood that embodiments of the present invention may be used in other industrial dishwashers, or for any application in which it is desired to measure the conductivity of an aqueous solution. Accordingly, the present invention is not to be construed as limited to specific examples herein.

Referring to Fig. 1, an industrial dishwasher 20 of the type described in US-A-4,756,321 is shown to include a conductivity measurement system 100 according to the present invention. System 100 is connected to a probe 52 having first 54a and second 54b electrodes submerged in a tank 35 of wash water used to wash dishes 38. In response to signals received from the probe 52, the system 100 provides control signals to a rinse pump 28, a detergent pump 32, and a sanitation pump 31 so as to ensure proper concentrations of a rinse agent, detergent, and a sanitation agent, respectively, within the wash water. As and when required, these materials are pumped from out of storage containers 30, 34 repectively 33. For a discussion of the general operation of the dishwasher 20, as well as the advantages realized thereby, see US-A-4,756,321.

Referring to Figure 2, the measurement circuit 100 includes a micro-controller 102 having an output terminal OUT

coupled to the first electrode 54a via a resistor R_1, where resistor R_{ON} models the on-resistance of the micro-controller 102. The resistor R_1 should be of a value suitable for the conductivity range of the wash water. In one embodiment, where R_{ON} is 60 Ω, a value of 200 Ω is chosen for resistor R_1, as explained in detail below. The micro-controller 102 also has an input terminal IN coupled to the first electrode 54a via a resistor R_2 which serves as a series protection resistor for the ADC input terminal. Although the resistor R_2 should thus be as large as possible in order to provide maximum protection for the ADC input terminal, the resistor R_2 must also be small with respect to the input impedance of the ADC 104 in order to preserve signal strength. In one embodiment, where the micro-controller 102 is able to operate accurately with a source impedance as high as 10 kΩ, a value of 4.7 kΩ is selected for the resistor R_2. The second electrode 54b is tied to ground potential. Block 200 is an electrical representation on the wash water in the tank 35, where capacitors C1 and C2 form a four-layer capacitor which models polarization of the wash water, and the impedance element Z models the impedance of the wash water. Increases in electrode contamination are modeled by reducing the size of the capacitors.

The micro-controller 102 includes an analog-to-digital converter (ADC) 104, a look-up table 106, a memory 108, a central processing unit 110, and a timing circuit 112. The micro-controller 102 is connected to a voltage supply V_{DC} and ground potential.

Referring also to the timing diagram of Figure 3, the micro-controller 102 generates at its output terminal OUT a DC pulse having a duration of T and an amplitude equal to V_{DC}. The voltage at the electrode 54a is measured at times

t_1 and t_2, where $t_1<t_2<T$, thereby giving measured voltages V_1 and V_2, respectively, which are stored in the memory 108. If there is no polarization within the wash water, the measured voltages V_1 and V_2 will be equal, as illustrated by case A of Figure 3. If, on the other hand, there is polarization, the current flow between the electrodes 54a and 54b will decrease between times t_1 and t_2 and, therefore, the voltage V_2 will be greater than the voltage V_1, as illustrated by case B in Figure 3. The rate at which the voltage at the electrode 54a changes is substantially linear and, therefore, compensation techniques discussed below utilize linear algorithms. However, where greater accuracy is desired, more complex, non-linear compensation techniques are used.

In calculating the conductivity of the wash water, linear regression is used to determine the voltage at electrode 54a at time t=0, i.e., at the beginning of the DC pulse. The voltage on the electrode 54a at time t=0 is given as:

$$V_0 = \frac{(V_1 * t_2) - (V_2 * t_2)}{(t_2 - t_1)}$$

Since the voltage V_0 corresponds to time t=0, the voltage V_0 is not influenced by the effects of polarization. Thus, the conductivity of the wash water, which is calculated using Ohm's law and the known K factor of the electrodes 54a and 54b, is not influenced by polarization within the wash water. In this manner, present embodiments compensate for polarization.

The difference between the first and second measured voltages, $V_{diff} = V_2 - V_1$, is indicative of the extent to

which the electrodes are contaminated. Accordingly, if the difference value exceeds a predetermined threshold corresponding to the maximum degree of acceptable electrode contamination, the micro-controller 102 generates an alarm signal alerting an operator of the system 20 that the electrodes 54a and 54b need to be cleaned or replaced. Further, in some embodiments, if the measured voltage V_0 at time t=0 is greater than a second predetermined threshold, the micro-controller 102 generates an alarm signal alerting the operator that the electrodes 54a and 54b are sufficiently contaminated so as to require servicing. In this manner, present embodiments facilitate servicing of the electrodes 54a and 54b before contamination becomes sufficient to degrade conductivity measurement accuracy.

In preferred embodiments, an inexpensive micro-controller such as, for instance, the 16C72, 16C73, or the 16C74, all available from Microchip Semiconductor Corp. is used for the micro-controller 102 in order to minimize cost. Since these micro-controllers are typically unable to take quick successive analog measurements, the first and second voltage measurements, V_1 and V_2, are sampled during two separate pulses, as explained below, where V_{DC}=5 volts, R_{ON}=60 Ω, R_1=200 Ω, R_2=4.7 kΩ, t_1=10 μs, t_2=15 μs, T=20 μs, and K=0.4.

Referring also to the flow chart of Figure 4, the micro-controller 102 generates at time t=0 a first DC pulse having an amplitude of 5 volts (step 1). The DC pulse induces an electric field between the first and second electrodes 54a and 54b which, in turn, results in current flow between the electrodes 54a and 54b in the wash water. At time t=10 μs, the micro-controller 102 samples the voltage at the first electrode 54a via resistor R_2 (step

2). The resultant analog voltage V_1 is provided to the micro-controller 102 via its input terminal IN and is thereafter converted to a digital voltage D_1 via the ADC 104. The digital voltage D_1 is stored in the memory 108 (step 3). At time t=20 μs, the micro-controller 102 terminates the first pulse, and the electrode 54a discharges to ground potential (step 4). After a predetermined period of time such as, for instance, 125 μs, the micro-controller 102 generates at its output terminal OUT a second DC pulse having an amplitude of 5 volts (step 5). The micro-controller 102 samples the voltage at the first electrode 54a at a time 15 μs after the second pulse is initiated (step 6). The resultant analog voltage V_2' is converted to a digital voltage D_2' via the ADC 104, and stored in the memory 108 (step 7).

As mentioned above, the conductivity measuring system 100 alerts an operator of the dishwasher 20 when electrode contamination exceeds acceptable levels. Here, the CPU 110 of the micro-controller 102 calculates the difference between the first and second stored digital (binary) voltages, $D_{diff}=D_1-D_2'$ (step 8), and then compares the difference voltage D_{diff} to a predetermined threshold voltage D_{th} (step 9). If the difference voltage D_{diff} exceeds the predetermined threshold voltage D_{th}, the micro-controller 102 activates an alarm signal to alert an operator of the dishwasher 20 that the electrodes need to be serviced (step 10).

The first and second voltages, D_1 and D_2', are then processed by the CPU 110 according to the above-mentioned linear regression algorithm to determine the digital

voltage D_0 on the first electrode 54a at the beginning of the first DC pulse, i.e:, at time t=0 (step 11). In one embodiment, the digital voltages D_1 and D_2' are stored as eight-bit numbers, where the binary number 255 corresponds to the analog value 5 (volts). This voltage at time t=0 and Ohm's Law are then used to calculate the conductance of the wash water (step 12). The conductance is converted to a detergent concentration using the look-up table 106 (step 13).

For example, where the digital voltages D_1 and D_2' are equal to 65 and 70, respectively, the value D_0 (at time t=0) is equal to ((65)(15)-(70)(10))/(10+15)=55. The analog voltage A_0, which corresponds to the digital voltage D_0, is therefore equal to (5)(55)/(255)= 1.08 volts. The current flowing in the circuit, i.e., through resistor R_1, is determined using Ohm's Law(V=IR). Here, the current is equal to (5-1.08)/(60+200)=0.0151 amps. The uncorrected resistance of the element Z, and thus the resistance of the wash water, is equal to (1.08)/(0.0148)=71.5 Ω. The corrected resistance of the wash water is determined by dividing the uncorrected resistance by K, i.e., (71.5)/(.4)=178.75 Ω, which gives a conductance of 1/(178.75)=0.00559 mhos (or siemens) = 5590 μsiemens. This measured conductance corresponds to the beginning of the DC pulse, i.e., time t=0, and is thus not influenced by polarization. In this manner, the conductivity measurement system 100 avoids the polarization-induced, erroneous detergent concentration measurements characteristic of conventional conductivity measurement systems.

The K factor is indicative of the electrodes' sensitivity and is typically between 0.1 and 10, where electrodes

having a small K factor are more suitable for measuring low conductances and, conversely, electrodes having a large K factor are more suitable for measuring large conductances.

A cell formed of an electrode pair "sees" a conductance divided by the K factor, e.g., a cell having a K factor equal to 0.1 sees a conductance that is ten times larger than the actual conductance of the wash water.

In some embodiments, the micro-controller 102 converts the analog voltage A_0 into Beta units, a unit of measure especially suited for use in determining the conductance of a detergent solution in an industrial dishwasher. Beta units are well known in the art and are thus not discussed herein. For a detailed discussion of Beta units, see U.S. Patent No. 4,756,321.

In the above example, the cell formed by electrodes 54a and 54b has a K factor equal to 0.4, the Beta Unit range is 60, and there are 3 counts per Beta Unit. The typical conductivity of wash water without detergent is about 600 µmhos, and the typical conductivity of wash water with a maximum detergent concentration is about 12,000 µmhos. Thus, the above cell formed by electrodes 54a and 54b actually "sees" wash water conductivities ranging from 600/0.4 = 1500 µmhos = 0.0015 mhos to 12,000/0.4 = 30,000 µmhos = 0.03 mhos. This conductivity range corresponds to a resistivity range of 1/(0.03 mhos) = 33.3 Ω to 1/(0.0015 mhos) = 666.7 Ω. Thus, the maximum Beta count, i.e., 180, corresponds to the minimum wash water conductance, i.e., R_{WATER} = 666.7 Ω. Using the voltage divider rule,

$$\frac{180}{255} = \frac{666.7\Omega}{(R_{WATER} + R_{ON} + R1)}$$

where $R_{ON} + R_1 = 277.8\ \Omega$. Since as mentioned earlier $R_{ON} = 60\ \Omega$, a value of about 200 Ω is chosen for the resistor R_1. Applicants found that a value of 200 Ω for resistor R_1 limited the current to a safe level.

In a preferred embodiment, the above-described pulse sequence is repeated every 250 ms so as to provide four conductivity measurements per second, although the interval between pulse sequences may be adjusted as desired for particular applications.

In the preferred embodiments, the conductivity measurement system 100 is implemented as software running on a micro-controller. Appropriate program modules may be stored on a CDROM, magnetic disk storage product, or any other computer readable data or program storage product. The software modules in the computer program product may also be distributed electronically, via the Internet or otherwise, by transmission of a computer data signal (in which the software modules are embedded) on a carrier wave.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as fall within the true spirit and scope of this invention.

Claims

1. A method of measuring representations of the electrical conductivity of an aqueous solution which compensates for polarization, said method comprising the steps of:
(a) providing first and second electrodes within said solution;
(b) generating, using a measurement circuit, a DC pulse to induce a current between said first and second electrodes;
(c) sampling the voltage at said first electrode at a first predetermined time interval after the generation of said DC pulse and generating a first voltage value in response thereto;
(d) sampling the voltage at said first electrode at a second predetermined time interval after the generation of said DC pulse and generating a second voltage value in response thereto;
(e) calculating, using linear regression and said first and second voltage values, the voltage at said first electrode contemporaneous with the generation of said DC pulse and generating a third voltage value in response thereto;
(f) producing, in response to said third voltage, a first signal representing the conductivity of said solution.

2. The method of Claim 1, wherein said first predetermined time interval is approximately 10 μs.

3. The method of Claim 2, wherein said second predetermined time interval is approximately 15 μs.

4. The method of Claim 3, wherein said DC pulse has a duration of approximately 20 μs.

5. The method of Claim 1, wherein said step (f) further comprises:
(f1) determining the current in said measurement circuit and generating a second signal in response thereto, said second signal representing the current in said solution;
(f2) dividing said second signal by said third voltage to generate said first signal representing the conductivity of said solution.

6. The method of Claim 5, wherein said solution contains a detergent having a concentration, said method further comprising the steps of mapping, using a look-up table, said first signal representing the conductivity of said solution to a third signal representing the concentration of said detergent.

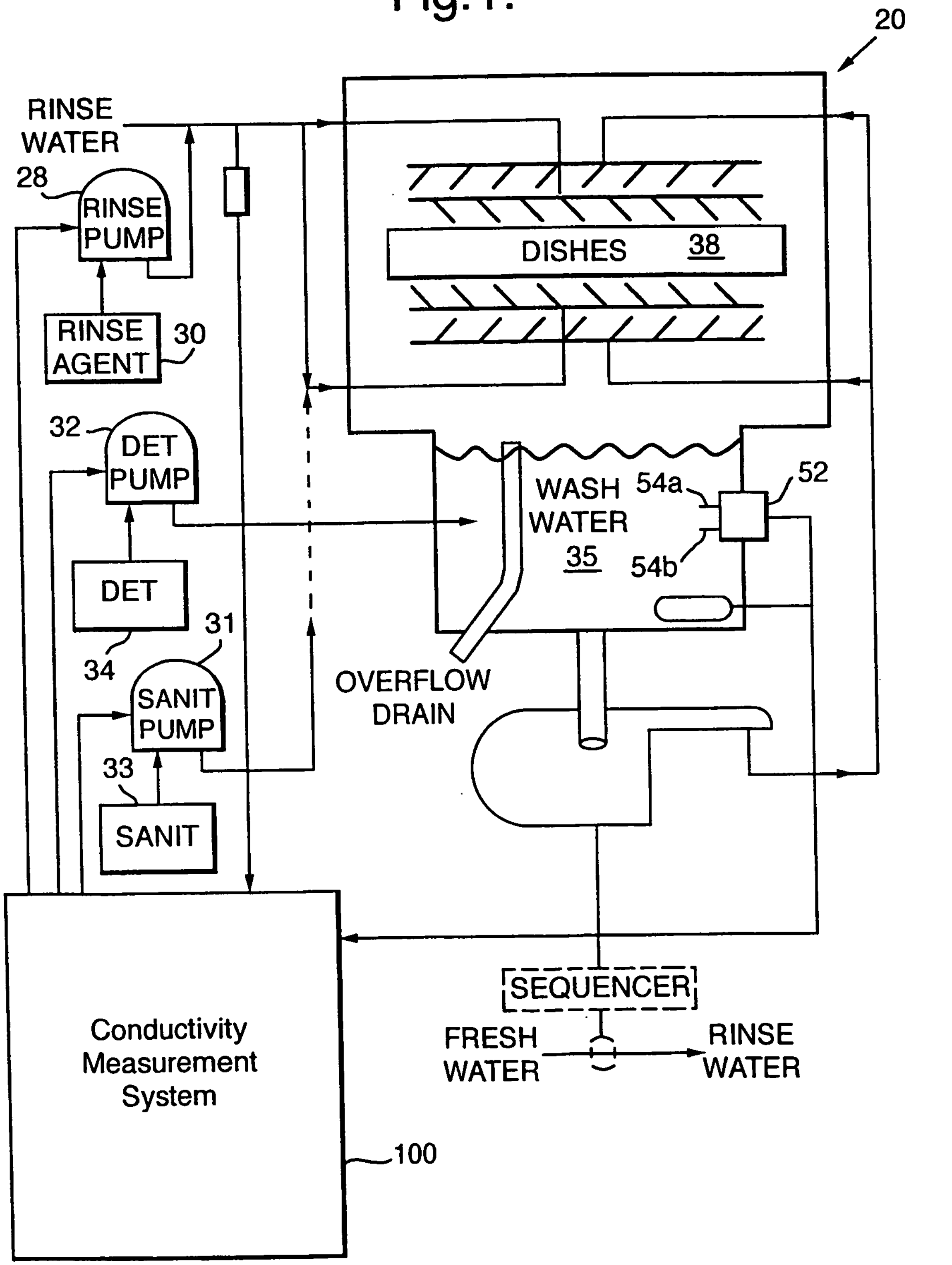
7. The method of Claim 1, further comprising the steps of:
(g) subtracting said first voltage value from said second voltage value to generate a difference voltage;
(h) comparing said difference voltage to a predetermined threshold voltage; and
(i) sounding an alarm if said difference voltage exceeds said predetermined threshold voltage, said alarm indicating that said electrodes are contaminated.

8. The method of Claim 1, where:
in step (b) said DC pulse comprises first and second DC pulses;

in step (c), said first electrode is sampled at said first predetermined time interval after the generation of said first DC pulse to generate said first voltage value; and in step(d), said first electrode is sampled at said second predetermined time interval after the generation of said second DC pulse to generate said second voltage.

9. The method of Claim 1, further comprising the step of:
(c1) generating, using said measurement circuit, a second DC pulse to induce current between said first and second electrodes;
wherein step (d) said first electrode is sampled at a second predetermined time after the generation of said second DC pulse.

Fig.1.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SANIT
DISHES
38
WASH
WATER
35
54a
54b
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DRAIN
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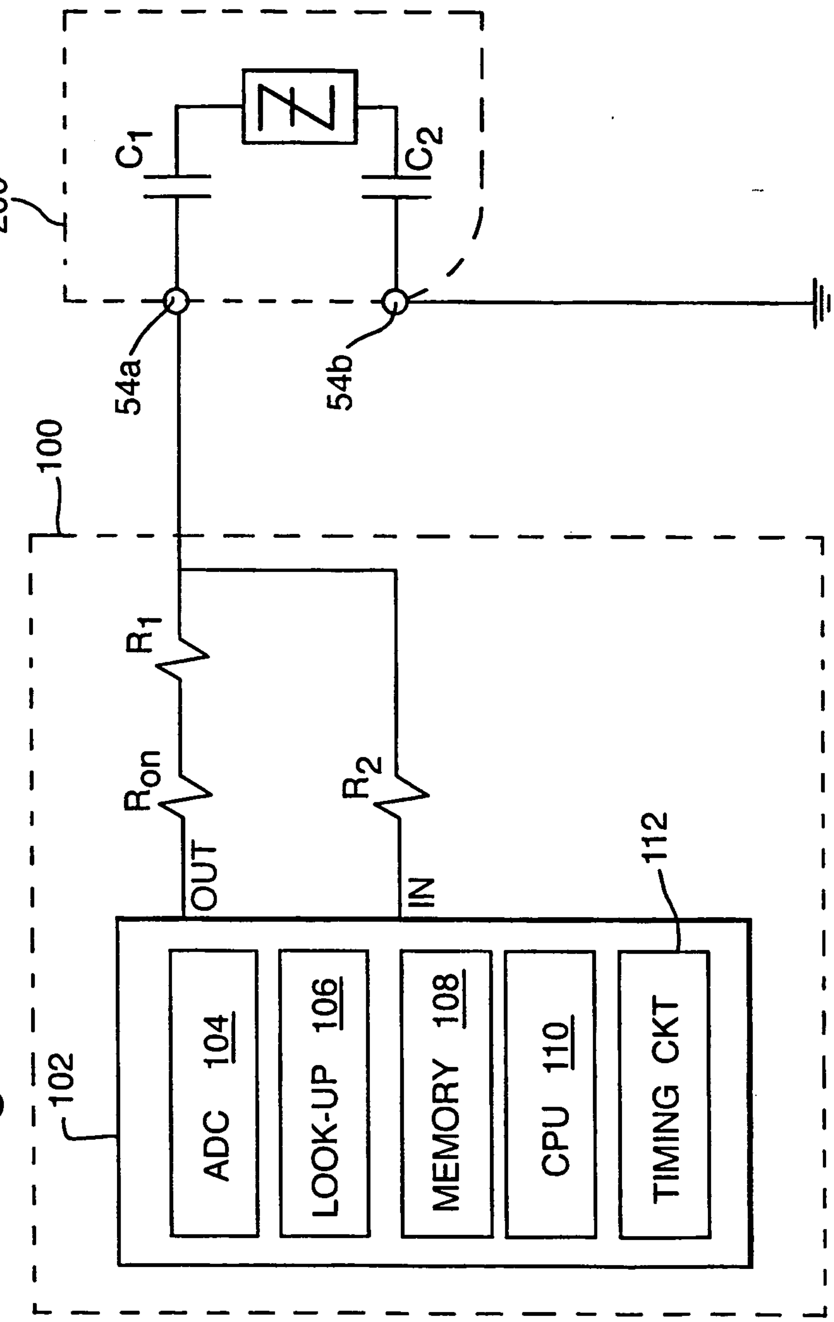
FRESH
WATER
RINSE
WATER
Conductivity
Measurement
System
100

Fig.2.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C1
C2
Z
54a
54b
100
R1
Ron
R2
OUT
IN
112
102
ADC 104
LOOK-UP 106
MEMORY 108
CPU 110
TIMING CKT

Fig.3.

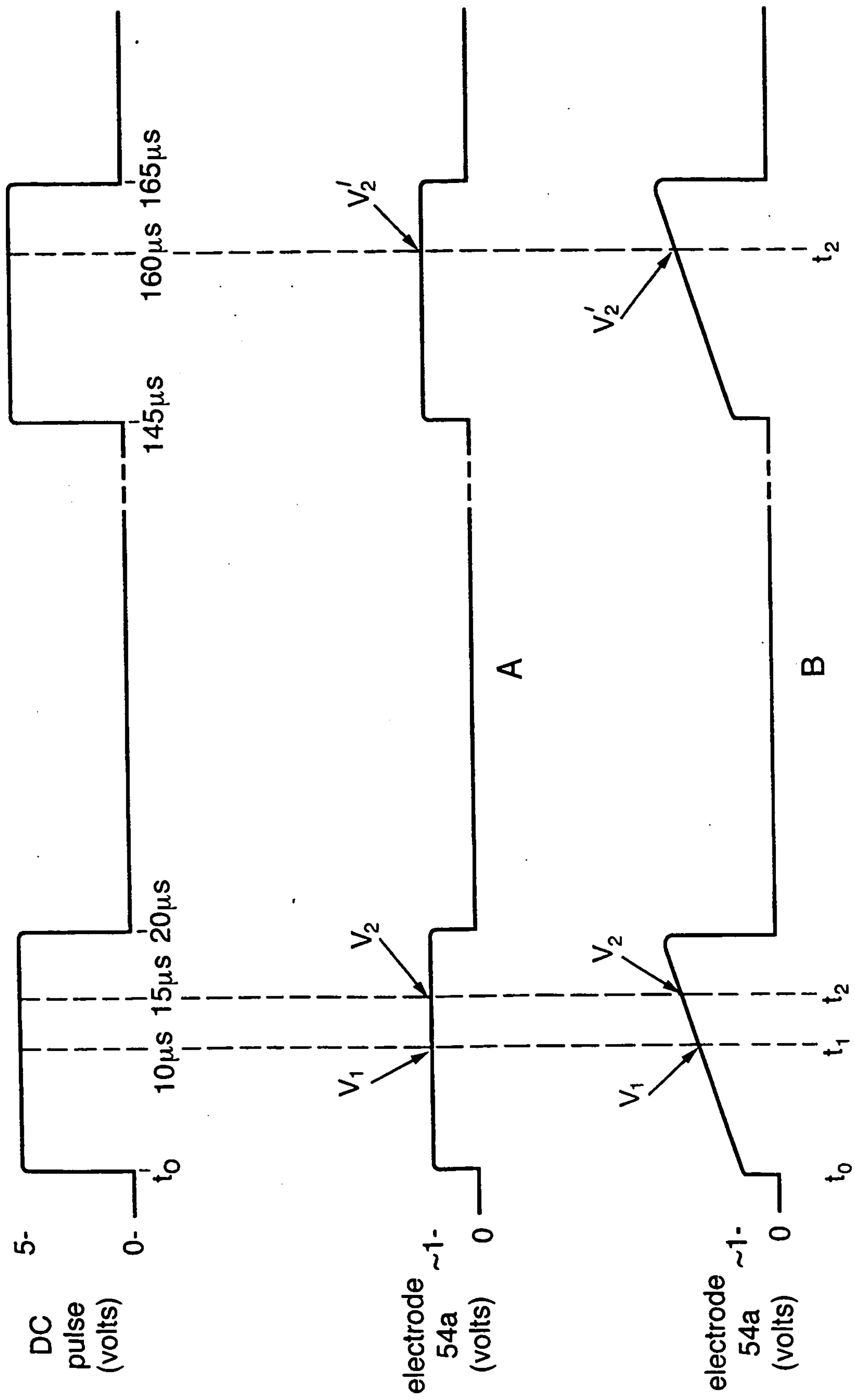
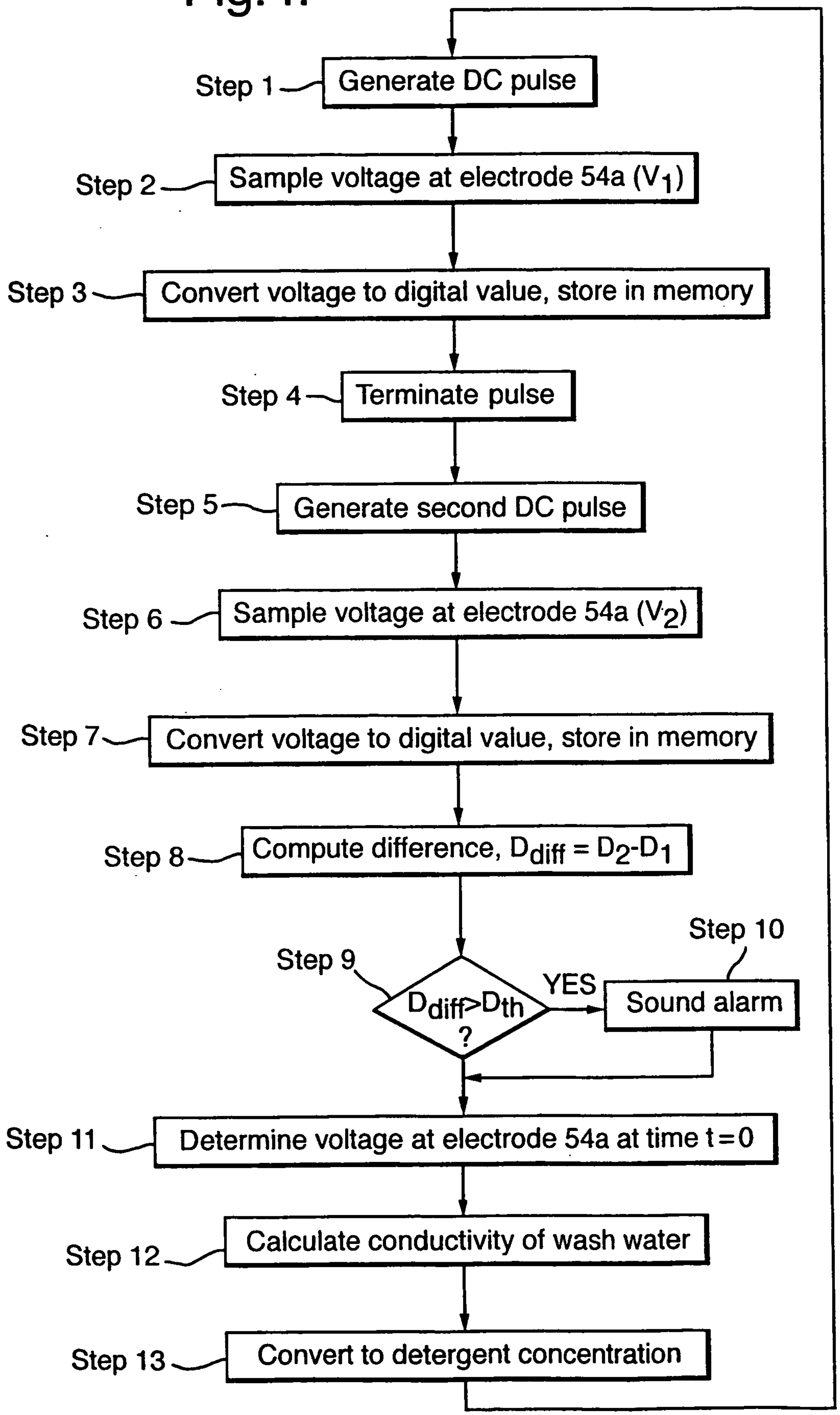

DC pulse (volts)
5-
0-
t_0
10µs
15µs
20µs
145µs
160µs
165µs
electrode 54a (volts)
~1-
0
V_1
V_2
V_2'
A
electrode 54a (volts)
~1-
0
t_0
V_1
V_2
V_2'
t_1
t_2
B

Fig.4.


Step 1
Generate DC pulse
Step 2
Sample voltage at electrode 54a (V_1)
Step 3
Convert voltage to digital value, store in memory
Step 4
Terminate pulse
Step 5
Generate second DC pulse
Step 6
Sample voltage at electrode 54a (V_2)
Step 7
Convert voltage to digital value, store in memory
Step 8
Compute difference, $D_{diff} = D_2 - D_1$
Step 9
$D_{diff} > D_{th}$?
YES
Step 10
Sound alarm
Step 11
Determine voltage at electrode 54a at time t=0
Step 12
Calculate conductivity of wash water
Step 13
Convert to detergent concentration

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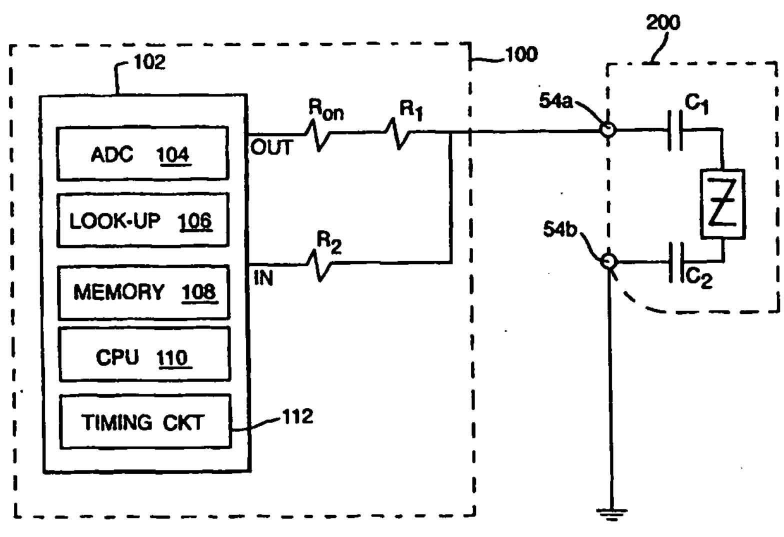

(57) Abstract

A conductivity measurement system provides one or more DC pulses to first and second electrodes submerged in an aqueous solution such as, for instance, the wash water of an industrial dishwasher. The voltage at the first electrode is measured at first and second predetermined times after initiation of DC pulse(s). Linear regression of the first and second measured voltages is used to calculate the voltage at the first electrode at the beginning of the DC pulse(s), i.e., at time t=0. The resulting voltage at time t=0 is then used to calculate the conductivity of the solution, thereby compensating for the effects of polarization. Further, the difference between the respective first and second measured voltages is compared to a predetermined threshold value to determine whether the electrodes are so contaminated that polarization compensation is no longer feasible, thereby signaling that the electrodes should be cleaned or replaced.

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/03252

A. CLASSIFICATION OF SUBJECT MAT
IPC 6 G01R27/22 D06F39/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01R D06F A47L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 4 808 930 A (KAISER DONALD F) 28 February 1989 (1989-02-28) abstract column 5, line 18 - line 36 column 8, line 3 - line 60 column 9, line 22 - line 41 column 11, line 51 - line 53 figures 5,6,8,10	1-5,7 5,6
Y	EP 0 288 099 A (YOKOGAWA ELECTROFACT BV) 26 October 1988 (1988-10-26) abstract column 3, line 12 - line 39 column 3, line 55 -column 4, line 12 claim 1 figure 1	5,6

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 August 1999	11 11 1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lopez-Carrasco, A

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP 99/03252

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-7

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

1. Claims: 1-7

Detergent concentration determination from conductivity measurements with electrode polarization compensation.

2. Claims: 8,9

Low rate sampling for voltage measurements.

INTERNATIONAL SEARCH REPORT

Int[illegible]on on patent family members

Intern[illegible]al Application No
PCT/[illegible]99/03252

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